Effect of visual restitution training on absolute homonymous scotomas

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There are two groups of rehabilitation techniques in homonymous visual field defects (HVFDs). One approach is to teach the patient how to explore the hemianopic field by compensatory eye movements.1 Another technique (visual restitution training [VRT]) is to achieve visual field improvement by using a computer-based program to visually stimulate partially defective areas, the so-called transition zone between the blind and normal visual field (VF).2 In this study, we evaluated the effect of VRT on absolute HVFDs.

Methods. We evaluated data of 16 patients with stable HVFDs resulting from lesions of the postchiasmal visual pathways, which occurred more than 1 year before baseline examination (table E-1 on the Neurology Web site at www.neurology.org). Exclusion criteria were age younger than 18 or older than 75 years, chronic systemic diseases, other neurologic or mental pathologies, bilateral HVFDs, central visual acuity less than 8/20, and other ophthalmologic diseases.

Briefly, in VRT,2 repetitive stimulation of a transition zone between the blind and normal VF was performed on a monitor of a personal computer at home for 1 hour daily (6 days a week during a 6-month period).

Assessment of (H)VFDs. Visual field examinations were performed three times before training to minimize perimetric learning effect and after 6 months of training in the Tuebingen Eye Clinic. Subjects were examined with threshold oriented, slightly suprathreshold static automated perimetry, using the Tuebingen Automated Perimeter (TAP: 191 locations within the central 30° VF, background luminance 10 cd/m²; stimulus characteristics: size 10°, duration 200 milliseconds, maximum luminance 1,000 cd/m²; if this luminance level could not be perceived after one repetition, this location was regarded as an absolute VF). Depths of relative VFDs were quantified by five luminance levels (1 through 5; 5 dB apart). Luminance level 0 was approximately 5 dB above the threshold of normal subjects.

A shift of the scotoma border by more than 2° was originally defined as a criterion for success in this study. A shift of 2° within the central region and approximately 5° in the “peripheral” region of the 30° VF would affect the “band” of test locations next to the vertical meridian, which is 12% of all stimulus locations (E = 0.12).

The extent of HVFDs was quantified by the proportion of absolute VFD locations in the total number of test locations (discounting the blind spot) for each eye. The difference in the ratio before and after training was defined as training effect (E). The correlation of effects on eyes of the same patient was taken into account by repeated-measures analysis of covariance. A second measure of visual restitution (the binocular effect) was defined as the proportion of locations with absolute VFDs in one eye and with a defect level of 5 or more at identical positions of the fellow eye. A third option was to compute the binocular effect for trained and untrained areas separately. Such a hunt for the best definition of success in the absence of a control group precludes the use of most inferential statistics and p values in particular. Intraindividual fractions were described by their mean and SD or the 95% reference band is shown for regressions from the proportion of TAP defects after training on proportions at baseline.

Perimetric quality control. Quality control was established by catch trials: 15 acoustic stimuli without subsequent visual stimulus presentation were randomly presented to check for false-positive responses. Another 10 slightly suprathreshold stimuli (8 dB) in the VF center were used for fixation control. False-alarm rates or missed central fixation stimuli rates below 20% of the presented response control trials were rated as “good,” as were fixation control rates above 80%.

As usual in ophthalmologic practice, the right eye (RE) was tested first.

This research followed the tenets of the Declaration of Helsinki and was approved by the Independent Ethics Committee. Written informed consent was obtained from all subjects after explanation of the nature and possible consequences of the study.

Results. Evaluation of absolute VFDs. Figure 1 shows the HVFDs of all 16 patients before and after training (for related quantitative data, see table E-1 and figure 2). The line of identity is completely included within the 95% reference band. The average improvement in absolute VFDs was eight test locations within the 30° VF. The mean E on the absolute VFDs was 0.05 (SD 0.05) in all REs and 0.05 (0.05) in all left eyes (LEs). In only two eyes of two patients (LE of Patient 07 and LE of Patient 13), E exceeded the critical value (0.12) for a relevant training effect.

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Assessment of binocular VF changes. Binocular changes in the TAP after training are shown in figure 3. For the entire 30° VF, the binocular $E$ was 0.04 (SD 0.03). The attributable fraction amounted to 0.08 (0.07) of the trained area and 0.01 (0.03) of the untrained region.

Discussion. Whether VRT stimulation, especially in the “transition zone” between the normal and the scotoma region, can induce a relevant enlargement of the VF is controversial.

Vision requires a highly specific neuronal organization, which is definitely established during early development. Furthermore, an improvement exceeding 4° within the central VF area would require a reactivation of a large area (approximately half of the visual cortex) because of the high cortical magnification factor of the macula and has therefore been regarded as improbable.

In contrast, several authors describe VF improvement after VRT and refer to brain plasticity after lesions of the visual system. Some authors propose that training can reactivate surviving neurons of the partially damaged cerebral structures, corresponding to the transition zone or islands of residual vision in the affected VF region.

According to the Magdeburg group, the average shift of the scotoma border in this cohort was 1.62°, which does not meet the originally defined criterion of success (2°). This shift was rated as a “significant” improvement in two recent articles. Significance of a statistical test does not implicate clinical relevance of the result. A minimum shift of 2° within the central and approximately 5° in the “peripheral” region of the 30° VF would result in $E = 0.12$, which seems to be a suitable criterion for benchmarking of relevance. We found $E > 0.12$ in only two eyes of two subjects. The fact that this “relevant” improvement occurred monocularly despite a binocular training indicates that the phenomenon may be at least partially due to nonspecific effects, such as test–retest variability. The considerable inter-eye variation in several other patients supports this interpretation.

Corresponding to our results, the Magdeburg group found only a slight improvement in the TAP from patients with postchiasmal lesions: they reported a mean shift of the scotoma border of only 0.4° (SEM 0.3°). However, in high-resolution campimetry (HRC), they found an average shift of the border of 4.9° (SEM 1.7°). Explanations for this may be methodologic differences between TAP and HRC, regarding stimulus luminance and arrangement, background luminance, classification of VFDs, and parameters assessing quality control.

It cannot be excluded that VRT may also stimulate exploratory strategies. However, the intended stable fixation for stimulating defined transition zones with this technique is not an efficient way to elicit compensatory gaze movements as already successfully realized by other training procedures. It remains unknown to what extent the improvement in VRT is due to a real VF enlargement or to fixation.
instability/random saccadic eye movements. With scanning laser ophthalmoscope microperimetry, which is corrected for eye movements, no relevant improvement could be found after training in the same cohort: in none of the subjects there was a relevant “homonymous improvement” after VRT, and just one patient showed a monocular improvement.10

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